Joint Program for the Development of

Digital Command Receiver Decoder (DCRD)

DRAFT

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Executive Summary

This document defines a joint program, initiated by the US Airforce as operators of the Eastern and Western Ranges and the NASA Goddard Space Flight Center, to develop space based systems to perform Range Safety functions which have historically been performed by ground based launch range hardware. The Range Safety functions being investigated include both launch vehicle tracking and flight termination commanding. The concept is to transmit, through a telemetry system, combinations of GPS and Inertial Measurement System tracking data located on a launch vehicle. NASA's TDRSS satellite system would be used to relay the telemetry data through NASA's communication network to the appropriate launch site data collection facility. Flight termination commands, initiated by a MFCO located at the launch site, would be transmitted by NASA's TDRSS satellite to the launch vehicle.

At the Eastern Range (ER) and Western Range (WR), all current Spacelift and Ballistic launch vehicles are equipped with an airborne systems capable of performing these functions. The requirements for these existing systems are detailed in EWR 127-1. The Range Safety function is not unique to the Eastern and Western Ranges. It is performed at a virtually all ranges nationally. The current method of performing this function requires ground systems to maintain a line of sight UHF link with the vehicles for the purposes of transmission of "encoded" commands to the vehicle to initiate ordnance and negate thrust or otherwise to destabilize the airborne vehicle. At the ER, in particular, this in-flight requirement extends to orbital insertion for Spacelift and establishes requirements for ER downrange FTS ground assets at Antigua, Jonathan Dickinson Island in Florida, and Argentina, and the use of NASA FTS ground assets at Bermuda and Wallops Island, VA. These ground stations are expensive to operate and maintain. In fact, NASA is in the process of closing its Bermuda facility because of cost and the AF has chosen not to assume responsibility for the facility from NASA. This has and will create future impacts to the Commercial launching agencies and the Range Safety mission at the ER. The DCRD project is about eliminating the requirement for downrange ground FTS assets at the ER and potentially has applications for the way the FTS function is performed nationally. The DCRD and its support systems will allow the downrange UHF line of sight links to be replaced with links established through White Sands and TDRSS forward link to the DCRD residing on the launch vehicle. With the virtual worldwide coverage provided by the TDRSS network, expensive permanent and portable downrange FTS capabilities which are currently required at the ER and many other ranges may be limited to the launch sites and in some cases eliminated altogether.

The space based concept, as envisioned, may use a Range Safety "box" located on the launch vehicle that contains all launch vehicle systems necessary to meet Range Safety launch requirements. This box has been coined the "Magic Box". Currently, the Range Safety function drives downrange launch support asset requirements. The Range Safety tracking requirement requires downrange data (radar and telemetry) assets to provide the Range Safety controllers positional and telemetry data. The "Magic Box" concept has the data and command control subsystems as an integrated components of a Range Safety System that would meet Range Safety requirements for each mission. This, it is envisioned, would allow consolidation of ground resources at the launch site and eliminate the need for downrange assets. The "Magic Box" could potentially be provided as a “kit” for the launching agencies. Since Range Safety would validate both the design and operational uses of the box, minimum Range Safety involvement would be required in prelaunch vehicle processing. Use of the space based TDRSS satellites makes this “Magic Box” feasible and will result in reduced launch vehicle processing and cost. This would produce major cost reductions in range infrastructure at the ER and WR Due to the worldwide coverage afforded by the TDRSS network, the space based concept would allow launch and landing sites to be located virtually anywhere worldwide with minimum or no down range assets.

If this concept can be developed within Range Safety requirements a significant launch operation cost savings can be realized through the elimination of requirements for downrange radar, telemetry, and command support. The US Airforce and NASA, as primary users of each launch range, have agreed to this joint program to determine if space based systems can meet Range Safety requirements and provide a significant launch range cost reduction.

The first phase of the joint program, the development of a Digital Command Receiver Decoder (DCRD) that meets Range Safety requirements and is compatible with TDRSS, is defined in this document. The DCRD is a new development and represents the major risk in this new concept. Previous launch vehicles have used TDRSS to transmit telemetry data from the launch vehicle to the launch range during the launch phase. The integration of the TDRSS- DCRD based FTS capability into a broader Range Safety System will be performed following the success of Phase 1.

This document defines areas of responsibility and the requirements and specifications for a DCRD. The ER and WR will be responsible for (1) funding for the development and testing of the DCRD and the launch site ground system, (2) developing the technical Range Safety functional requirements for the DCRD, (3) providing technical expertise in Range Safety requirements and testing of the DCRD, and (4) providing technical expertise in launch operations and real time range safety systems. NASA will be responsible for (1) procurement of the DCRD, (2) developing the technical requirements of the DCRD to meet TDRSS compatibility, (3) developing the ground system used at the launch site, (4) providing technical expertise to the project, and (5) providing program management.
Both the ER/WR and NASA will provide technical experts to review program status and system designs.

Phase I of the DCRD project will answer the critical question, “ Can the FTS function be performed through TDRSS and the DCRD with roughly the same level of reliability and timeliness as the existing UHF FTS? This will be accomplished by construction of a DCRD engineering unit that is designed to meet Range safety requirements and is tested with TDRSS and compatible ground assets.

The latter part of Phase 1 will consist of using the proven DCRD design from early Phase 1 activities and constructing two qualification test units. These units will be subjected to environmental and qualification testing very similar to that currently performed on UHF FTS systems and ultimately one unit will be flight tested on a launch vehicle, to be determined. The system will be exercised using TDRSS and TDRSS compatible ground systems during the test flight and launch vehicle telemetry will validate correct operation of the DCRD flight unit and TDRSS compatible ground systems. The goal of Phase 1 is to have a complete validation of the overall concept and a DCRD design and unit that Range Safety would certify as operationally useable.

Once this is verified then the next step, Phase Two, is to determine if the TDRSS network can be used to relay the other critical element of the Range Safety function, launch vehicle position data and integrate these functions into a single box. The ambitious step is to integrate the Range Safety FTS and positional data requirements into a single “box” which has an RF interface at the launch head through ground systems and downrange with TDRSS. The system would be independent of all launch vehicle systems and potentially Government furnished. This is the long-range goal. The immediate issue is to produce a DCRD.

1.0 INTRODUCTION

1.1 Overview

This document defines a joint program between the US Air Force, as operators of the Eastern and Western Ranges, and the NASA Goddard Space Flight Center to develop space based systems to perform Range Safety functions which have historically been performed by ground based launch range hardware. The Range Safety functions being investigated include both launch vehicle tracking and flight termination commanding. Phase 1 of this effort is the development of a Digital Command Receiver Decoder (DCRD), a ground system for commanding the DCRD, and the development of the specifications for a ground transmitter to emulate TDRSS. Phase 2 will integrate the DCRD and a tracking subsystem system into a TDRSS compatible "box" that meets Range Safety requirements and procurement of the ground transmitter. Phase 2 will be addressed later in the program after Phase 1 is successfully completed.

Phase 1 has three parts, A, B, and C.

> **Part A** will answer the question, " Can the FTS function be performed through TDRSS and the DCRD with roughly the same level of reliability and timeliness as the existing UHF FTS?". This will be accomplished by the construction of a DCRD engineering unit.
>
> **Part B** is when the DCRD engineering unit will be tested with TDRSS and compatible ground assets. Upon successful completion of Part A, a review of the project and the development of Part C specifications will occur during Part B.
>
> **Part C** of the DCRD project will consist of constructing two DCRD qualification test units and a ground subsystem for commanding the DCRD. The test units will be subjected to environmental and qualification testing very similar to that currently performed on UHF FTS systems and ultimately one unit will be flight tested on a launch vehicle, to be determined. The system will be exercised using TDRSS and TDRSS compatible ground systems during the test flight and launch vehicle telemetry will validate correct operation of the DCRD flight unit and TDRSS compatible ground systems. The goal of Part C is to have a complete validation of the overall concept and a DCRD design that Range Safety would certify as operationally useable.

1.2 Scope

This document defines the responsibilities and requirements for completing Phase 1 Parts A, B, and C.

1.3 Roles and Responsibilities

ER, WR, and NASA will provide technical experts to review program status and system designs. The ER, WR, and NASA have established the following areas of responsibility:

A. The ER and WR will be responsible for:

1.) Funding for the development and testing of the DCRD and the launch site ground system(s),

2.) Developing the technical Range Safety functional requirements for the DCRD,

3.) Providing technical expertise in Range Safety requirements and testing of the DCRD, and,

4.) Providing technical expertise in launch operations and real time range safety systems.

B. NASA will be responsible for:

1.) Procurement of the DCRD,

2.) Developing the technical requirements of the DCRD to meet TDRSS compatibility,

3.) Developing the ground system used at the launch site,

4.) Developing a system plan that meets Range Safety total latency requirements,

5.) Providing technical expertise to the project, and

6.) Providing program management.

1.4 Schedule

a. NASA and the AF will determine the scheduling milestones for each part. Phase 1 Part A will be accomplished over a 12 month period. Part A testing may be performed at NASA. Phase 1 Part B will be accomplished over a 3 month period. Phase 1 Part C will be accomplished over a 12 month period. Part C testing will be performed at the ER or WR (TBD). Refer to Appendix A for a generic timeline which coincides with the time frames noted.

1.5 Products

A. Phase 1 Part A will produce:

1.) An engineering unit DCRD which meets the requirements of Section 3, 2.) A command subsystem capable of initiating the commands defined in Section 3**,** and

3.) Design specifications for a ground TDRSS transmitter.

B. Phase 1 Part B will produce:

1.) Specifications for two qualification DCRD units

2.) A flight test plan.

C. Phase 1 Part C will produce:

1.) An acceptable Space Based DCRD,

2.) Transmission system, and,

3.) Launch Vehicle Test Flight.

1.6 Reference Documentation

A. SNUG

B. EWR 127.1

2.0 PHASE 1 PART A TDRSS DIGITAL COMMAND DESTRUCT RECEIVER DECODER (DCRD): PART A GOALS AND SPECIFIC TASKS

2.1 Phase 1 Part A: TDRSS DCRD Concepts, Design, and Development Overview

Part A concepts, design, and development activities include completing various tasks that demonstrate the feasibility of a TDRSS compatible DCRD. During development of the DCRD, requirements shall be performance in nature to allow the contractor the latitude to achieve a system that is feasible. To accomplish this, the Part A DCRD shall be an engineering unit with design requirements and design goals. The Part A goals are two types:

- Type 1 goals are overall system requirements for which the DCRD shall contribute.
- Type 2 goals are environmental requirements that will be imposed as requirements for Qualification Unit Development and Proof of Concept Testing (Part C).

The DCRD design shall meet Part A requirements and shall be developed to meet the goals during Part C development. The technical demonstration during Part A will demonstrate compatibility with TDRSS. The technical demonstration during Part C shall complete qualification testing and integrate the DCRD hardware onto a launch vehicle to support a test flight.

2.1.1 Phase 1 Part A Specific Tasks

A. Develop a fully functional DCRD engineering unit to support proof of concept, initial test, and evaluation. Functionality of this unit will be demonstrated in a non-operational flight environment (e.g. no shock and/or vibration) but will include performance testing and testing at temperature extremes.

B. Develop a detailed concept of the ground system that would support operational use of the DCRD demonstration flight. This task would address developing the equipment and software needed to generate MFCO commands, format the commands into TDRSS compatible messages, and transmit the commands to the White Sands Complex (WSC).

C. Format and timing for command delivery to the WSC will be based on NASA-provided Interface Control Drawings (ICD). This task should include a full description and demonstrate a clear understanding of the WSC systems that will accept range commands and transmit to the Tracking and Data Relay Satellite System (TDRSS). The equipment shall develop commands defined in Section 3. Completion of this task will include an end-to-end statement of the equipment, software, and communications links required to initiate commands from a remote terminal to TDRSS. Ideally, this capability should resident on a laptop computer with modem interface capability to WSC.

D. Propose a design of a TDRSS compatible ground transmitter to command the DCRD.

E. During Part A, the following additional tasks will be performed:

1.) The TDRSS-to-DCRD interface. The resulting ICD should address TDRSS existing capabilities and planned upgrades for the forward link.

2.) Development and implementation of a RF system to include antennas, couplers, and cables. The purpose of this development is to ensure the DCRD system functions reliably.
Note: The DCRD and the RF system designs are dependent on each systems performance parameters. This task will ensure that the prototype unit can be directly implemented into a final design without design changes driven by vehicle RF parameters

3.) TDRSS/DCRD link margin. This task will define the signal structure for the selected link forward service and provide a complete link budget to show that command and control can be maintained through the full range of operational conditions ie. both environmental and vehicle attitude. Link margins are defined in Section 2.1.2.1. A link margin analysis shall consider the maximum system latency time and system security requirements.

4.) A successful demonstration of the prototype DCRD performance. This bench-level test will confirm that the DCRD and supporting RF system can receive, process, decode, and react to commands transmitted on the TRRSS forward link. If possible, the demonstration should employ the actual TDRSS forward link with input power calibrated on the ground to represent expected power levels in the operational environment.

5.) Development of a coding scheme that provides the same level of protection against acceptance of inadvertent commands as the current high-alphabet scheme used on the EW and WR today. The proposed system shall be designed to minimize operational impacts (e.g. security and code loading). In addition, the proposed signal structure shall be immune to jamming from intentional and unintentional radiating sources.

6.) Identify a potential launch vehicle to be used for the flight demonstration in Part C. Interface requirements shall be developed which allows the proposed design to interface with the launch vehicle (e.g. power, RF and TM systems).

2.1.2 Phase 1 Part A Design Goals

2.1.2.1 Type 1 Goals: Overall System Design

A. General System Goals

1.) Reliability

The reliability goal utilized in the design shall be a minimum of .999 for both the DCRD and the ground transmitter and commanding unit.

2.) RF Link Analysis

A link budget will be constructed for the TDRSS-to-DCRD link. The budget will consider destructive interference effects from the proposed antenna system. The budget must demonstrate 9 dB of margin in 95% of the spherical coverage for both DCRDs.

When two or more spatially separated TDRSS satellites are used and either TDRSS can effect a command in both of the two DCRDs, the following define the TDRSS-to-DCRD link margin and spherical coverage:

Link Margin:

- For any given vehicle orientation at least one command path shall maintain a 9 dB margin as a design threshold to each receiver.
- For any given vehicle orientation at least one command path shall maintain a 12 dB margin as a design goal to each receiver.

Spherical Coverage:

- When two or more command transmission paths are used, at least one path shall maintain a 9 dB link margin to each receiver for any vehicle orientation.
- When one transmission path is used, that path shall maintain a 9 dB link margin to each receiver over 95% of the sphere.

B. DCRD

1.) Secure Receiver Goals

The secure receiver shall meet the requirements, as they pertain to the TDRSS DCRD design, in FTS Standard Command Receiver and Decoder General Design Requirements and Standard Receiver sections of Chapter 4, 127.1, and the following additional requirements.

2.) Secure Digital Command Receiver and Decoder Design Goals

(a) Secure Decoder Response Time**{** XE "Secure Decoder Response Time" **}**. The time interval between the complete reception of the 11th character (tone pair) of the command message at the front end of the receiver and the occurrence of the respective decoder output shall not exceed 25 milliseconds.

(b) Secure Decoder Tolerance**{** XE "Secure Decoder Tolerance" **}**. Decoder tolerances shall be specified.

3.) DCRD Piece Parts Selection

Piece parts design used in Phase One shall meet ELV-JC-002D requirement (as tailored). Note: although ELV-JC-002 parts must be used, the additional upscreening, DPA, and LAT are not required for the Part A 1 prototype unit.

4.) DCRD Voltage and Current Parameters

The input voltage range for the DCRD shall be 18 through 36 volts (goal). The components shall meet the requirements of this Chapter at any voltage level between the minimum and maximum specified. The components shall not produce an output or be damaged because of low or fluctuating input voltage.

5.) DCRD Transcient Voltages

All DCRD and vehicle system interface components containing reactive elements such as relays, electrical motors or similar devices, that are capable of producing transient voltages shall be provided with suppression circuitry to prevent interference or damage to other DCRD components.

6.) Voltage Protection

(a) DCRD components shall not be damaged by the application of up to 45 volts, direct current (Vdc) or the open circuit (OCV) of the power source, whichever is greater.

(b) This voltage shall be applied in both normal and reverse polarity modes to the component power input ports for a period not less than 5 min.

7.) Series/Redundant Circuits

DCRD components that use series redundant branches in the firing circuit to satisfy the no single failure point (SFP) requirement shall provide monitoring circuits or test points to verify integrity of each redundant branch after assembly.

8.) DCRD Switch and Selection Criteria

The DCRD should be capable of processing all commands during a 50 ms power dropout. The latched Arm and Destruct commands shall remain latched after a 50 ms dropout.

9.) Reacquisition

Reacquisition time following power loss/signal dropout must be specified and tested. Expected reacquisition time must be identified by PDR. As a goal, reacquisition time should be less than 500 ms.

10.) DCRD Continuity and Isolation

The isolation resistance of the output pin to input pins and case ground shall not be less than 2 megohms. The resistance from each pin to common return and/or case ground shall also be specified. Measurements that are polarity-sensitive, such as those containing diodes, shall be identified. Significant pin-to-pin measurements shall be included where their inclusion will provide meaningful data relative to the health of the component.

11.) Circuit Isolation

Ungrounded circuits, capable of building up static charge, shall be connected to the structure by static bleed resistors of between 10 kilohms and 100 kilohms.

12.) DCRD Circuit Protection

The DCRD firing circuitry shall not contain fuses or similar type protection devices. The ARM output command of DCRD shall be protected against over current including a direct short by such means as fuses, circuit breakers, and limiting resistors.

13.) DCRD Watchdog Circuits

Watchdog circuits that automatically shutdown or disable DCRD circuitry when certain parameters are violated, such as snap-on and snap-off circuits in power supplies, shall be specifically approved by Range Safety. The parameters shall be specified in the component specification and included in testing.

14.) Self-Test Capability

The DCRD microprocessor shall have the capability to perform a self-test (error detection) and output the results via telemetry. The self-test shall be capable of initiation by POWER ON and upon receiving a special test command. Failure of a self-test shall not intentionally disable the component. The execution of a self-test shall not inhibit the processing intended function of the unit or cause any output to change state. Test parameters used for the self-test shall be approved by Range Safety.

15.) Interference Protection

The DCRD shall have a design goal of meeting the requirements of MIL-STD-461, Class A-2, Methods CE 102, CE 106, CS 101, CS 103, CS 104, CS 105, CS 114, CS 115, CS 116. Part A One design should, to the maximum extent possible, anticipate the intended operational environment for the vehicle S-Band telemetry transmitter and ensure that vehicle S-Band emanations will not adversely affect DCRD operation.

16.) Monitor and Checkout Circuits

The function of the DCRD shall not be affected by the external shorting of a monitor circuit or by the application of any positive or negative voltage between 0 and 45 Vdc for up to 5 min to an DCRD monitor circuit. Monitor circuit shall be designed so that application of operational voltage shall not cause inadvertent function or loss of function nor cause the DCRD to be armed. Resolution, accuracies, and data rate for monitor circuit outputs shall be specified and approved by Range Safety.

B. Antenna

1.) Antenna System Conceptual Design

The 3 dB bandwidth of the antenna shall take into account the bandwidth information content plus Doppler offset. For example, for direct sequence coding the bandwidth shall be twice the spreading code plus margin for Doppler resulting from vehicle dynamics. Antenna system components should be designed for a nominal 50 ohms impedance. The antenna system should have a Voltage Standing Wave Ratio (VSWR) of 2:1 or less.

2.) Antenna System Compatibility

The antenna system shall be full compatible with the TDRSS forward link including polarization, center frequency, bandwidth, and system spherical coverage.

C. Ground System (TBD)

2.1.2.2 Type 2 Goals: Environmental Design Margins

The prototype design of the DCRD and RF system shall anticipate environmental design margin requirements for Part C to the maximum extent possible. The intent is to minimize design changes between the prototype and flight units. The qualification margins utilize the maximum predicted environment of the proposed test vehicle plus margin. Since the qualification test unit will become the flight test article (i.e. proto-qual unit), a proto-qual test will be performed to qualification test margins described below. Therefore, the design shall ensure a margin over the required proto-qual test levels. In the absence of flight data, the minimum environmental levels shall be used.

A. Sinusoidal vibration

1.) Design: 12 dB above MPE
2.) Protoqual Test: 6 dB above MPE or protoqual test, whichever is greater

B. Random vibration

1.) Design: 12 dB above MPE or proto-qual test, whichever is greater
2.) Proto-qual Test: 6 dB above MPE - Minimum level 12.2 Grms

C. Acoustic

1.) Design: 12 dB above MPE or proto-qual test, whichever is greater
2.) Proto-qual Test: 6 dB above MPE

D. Shock

1.) Design: 12 dB above MPE or proto-qual test, whichever is greater
2.) Proto-qual Test: 6 dB above MPE - 1300 G peak @ 2000 Hz Pyroshock spectrum

E. Component Interference Requirements

Special emphasis shall be placed on design and testing to ensure that the vehicle S-Band telemetry output does not interfere with the DCRD. Electro-magnetic compatibility (EMC) and electromagnetic conducted emission and susceptibility testing shall be conducted to verify that the DCRD is sufficiently isolated from a vehicle S-Band telemetry output.

3.0 PHASE 1 PART A TDRSS DIGITAL COMMAND DESTRUCT RECEIVER DECODER (DCRD): REQUIREMENTS

3.1 Phase 1 Part A Requirements Overview

Phase 1 Part A requirements are provided for the DCRD, the antenna system, and the supporting ground system to be stationed near the launch head. A requirement of particular interest in this endeavor is overall system latency; hence, the following subparagraph is specific to latency requirements.

3.2 System Latency

Although each component of the overall system has specific requirements, one requirement that must be under constant consideration is overall system latency. This requirement must be met to effectively provide Range Safety Command Destruct operations via the TDRSS.

System latency, defined as the time from the start of a vehicle failure until a flight termination action is effected, is an issue that involves the DCRD as well as other systems. Total system latency of 5-8 seconds is required. The MFCO reaction time of 3 seconds in included in this time. The DCRD and all subsystems shall be designed to minimize its contribution to this time.

The latency time of the DCRD becomes part of the overall system latency time and therefore the design shall minimize this time. Design of equipment and software needed to generate MFCO commands. Current Range Safety system latency for this subsystem is approximately 1 second for secure systems and 50 mill-seconds for non-secure systems.

3.3 DCRD Design Requirements

A DCRD shall be developed which supports both a secure and a non-secure launch operation. This capability may be incorporated into a single DCRD or two versions. In either the secure or non-secure version the DCRD shall receive, process, and provide output(s) for the following six commands: ARM, DESTRUCT, OPTIONAL, PILOT TONE, TEST, and RESET. Outputs for each command are provided to TM as well as performing the designated function. Each of these commands is defined in the Table 3.3 below.

Table 3.3

Command	Description
Arm	An Arm command is Range Safety Command issued as preparatory to the Destruct command. In liquid fueled engines this command normally initiates engine shutdown. In all cases, a valid arm request must be successfully decoded and latched prior to the Destruct command in order for flight termination to occur.
Destruct	In the presence of a valid latched Arm Command, The successful decoding of a valid Destruct command initiates the sequence for ordinance firing or flight termination.
Optional	The Optional command is normally not a Range Safety requirement. It is made available for potential use by the range users. It is currently most used to initiate "safing" of the vehicle Flight Termination System (FTS) in- flight when no longer required by Range Safety.
Pilot Tone	The Pilot tone is a single function command. For the secure receiver it is not used in the High Alphabet scheme. The Pilot Tone is normally commanded throughout flight to indicate in-flight functionality of the receiver-decoder. A Command Receiver Decoder (CRD) ouput indicating correct receipt and decoding of the command is sent to the ground via TM for display and/or recording. It does not interfere with processing of higher priority commands.
Test	A Test command is a command message in the high alphabet format that can be radiated open loop to validate correct functioning of the CRD prior to launch
Reset	Resets the latched output command (Arm, Destruct, Test, or Optional) of a CRD.

DCRD Commands

3.3.1 General DCRD Design Requirements

A. General Command, RF, Electrical Requirements

1.) ARM, DESTRUCT, and optional output commands shall be routed through a separate connector(s) from input power, monitor circuits, and RF inputs.

2.) RF inputs shall be routed through a dedicated connector. After initial adjustment, the DCRD shall perform in accordance with the requirements of this section without subsequent adjustment.

3.) The DCRD shall be capable of delivering the specified power to the specified load on each output at any DCRD input power supply voltage level between the minimum and maximum.

4.) The maximum leakage current through the command destruct output port shall be specified in the procurement specification and shall not be more than 50 microamperes.

B. DCRD Interference Protection

Part A One Conceptual Design should anticipate the need to meet MIL–STD-461 methods CE102, CE106, CS 101, CS 103, CS 104, CS 105, CS 114, CS 115, CS 116 as tailored for S-Band, direct sequence code application.

C. DCRD Operating Frequency Band

The DCRD shall be compatible with the TDRSS S-Band operating frequency including specification drift, drift rate, and Doppler shifting.

D. DCRD RF Sensitivity

RF sensitivity shall support the overall link budget defined in 2.1.2.1

E. DCRD Power Consumption

The power consumption of the DCRD shall support he proposed vehicle power source capacity in Part A 2.

F. DCRD Maximum Usable RF Input

The DCRD shall be capable of operating within its performance requirements during and after application of TBD dBm.

G. Standard Receiver Response Time

The response time of each function shall be between 4 milliseconds and 25 milliseconds from the time the command is received at the DCRD.

H. Immunity to In-Band Signals

The DCRD shall receive, process, decode, and respond to all commands in the presence of TBD signal level within TBD frequency band with TBD spectral characteristics.

I. Simultaneous Processing

The DCRD shall provide a minimum of 3 real-time simultaneous processing of multiple transmitting stations. Example – simultaneous processing of transmitted signals from a launch-area site and two TDRSS downlinks. If the signal path from one station is lost (example – plume impingement on the launch-area station to vehicle path), processing on the TDRSS path shall remain continuous, uninterrupted, and fully capable of executing all commands.

J. Carrier/Noise Ratio

C/N for each DCRD channel shall be provided as a telemetry output.

K. Application of Power

The DCRD shall meet all performance requirements within 5 minutes of application of power.

L. Immunity to Out-of-Band Signals

The DCRD shall receive, process, decide, and respond to all commands in the presence of large interfering signals at C-Band, UHF, and X-Band. Signal amplitudes are TBD.

M. Output Channels for Commands

The DCRD shall provide telemetry outputs for the ARM, DESTRUCT, OPTIONAL, PILOT TONE, TEST, and RESET commands.

N. ARM (Engine Shutdown) Command

The arm output shall be active only after successfully decoding an encoded ARM command and shall stay on continuously.

O. DESTRUCT Command

The destruct output shall be active after successfully decoding a DESTRUCT command with a currently active ARM command. The ARM and DESTRUCT command shall latch on once the command is issued.

P. Synchronization. TBD

Q. RESET Command

The DCRD shall have the capability to reset a latched command by processing a RESET command.

R. Memory Life

The DECR following coded message loading into the DCRD, the codes shall remain in memory for a period of not less than 180 days without primary power being reapplied.

S. Electrical Connector Capacity

Connectors shall be capable of adequately handling 150 percent of the design load for continuous duty signals of 100 sec or more. For continuous duty signals less than 100 sec duration, the connector shall be selected to conform to the insulation temperature class of the inert materials.

3.3.2 Secure DCRD

A. Secure DCRD Policy

1.) A secure DCRD shall comply with the national policy directive, National Policy on Application of Communication Security to Command Destruct System, issued in 1988.

2.) Secure DCRDs are designed to prevent inadvertent flight termination command outputs caused by unauthorized and/or accidental radio transmissions.
{ XE "FTS Secure Command Receiver and Decoder Design" **}**
3.) The use of secure DCRDs is not a Range Safety requirement, but when used it shall meet all Range safety requirements.

B. Secure Receiver

The secure receiver shall be designed to be TDRSS compatible and meet the applicable requirements in FTS Standard Command Receiver and Decoder General Design Requirements and Standard Receiver sections of Chapter 4, 127.1, and the following additional requirements. The threshold sensitivity and message security requirements need to meet the link margins defined by the Spacebased System.

C.) Secure Decoder

The following are operational requirements for the DCRD. Technical requirements shall be developed during Part A and finalized during Part B.

1.) Secure Decoder General Design Requirements{ XE "Secure Decoder General Design Requirements" }

(a) The secure decoder design shall be approved by Range Safety.

(b) The Ranges will consider any design that satisfies the manager of the National Telecommunications and Information Systems Security (NTISS) requirements while maintaining Range Safety reliability requirements.

(c) Secure decoder designs shall be compatible with TDRSS transmitting equipment.

2.) Secure Decoder Minimum Outputs{ XE "Secure Decoder Minimum Output Channel" }

(a) The secure decoder is required to output the following functions: ARM, DESTRUCT, OPTIONAL, PILOT TONE, TEST COMMAND, RESET COMMAND.

Note: PILOT TONE is the name of one output function, it doesn't infer a tone signal.

(b) Any additional decoder output channels shall be approved by Range Safety

3.) Secure Decoder Logic Sequence{ XE "Secure Decoder Logic Sequence" }

(a) The decoder input command message shall consist of 11 characters.

(b) The characters shall form a high-alphabet code.

(c) The secure high-alphabet command codes are provided to the Range User by the National Security Agency (NSA).

4***.) Secure Decoder ARM (Engine Shutdown) Command{ XE "Secure Decoder ARM (Engine Shutdown) Command" }***

The arm output shall be active only after successfully decoding a high-alphabet encoded ARM command and shall stay on continuously.

5.) Secure Decoder DESTRUCT Command

The destruct output shall be active only after successfully decoding a high-alphabet encoded DESTRUCT command and a currently active ARM command and shall stay on continuously.

6.) ***Secure Decoder Automatic RESET Command*****{** XE "Secure Decoder Automatic RESET Command" **}** (a)The DCRD may be designed to have the capability to reset a latched output command by processing a RESET command.

(b) The RESET command capability shall be erased from the flight DCRD prior to launch.

7.) ***Secure Decoder Memory Life*{** XE "Secure Decoder Memory Life" **}**

Following coded message loading into the receiver, the codes shall remain in memory for a period of not less than 120 days without primary DC power being applied.

3.3.3 Secure and Non-Secure DCRD

A. <u>Secure and Non-Secure DCRD Command Processing</u>

The DCRD shall receive, process, and provide appropriate output to drive TM for the following commands:

1.) ARM
2.) DESTRUCT
3.) OPTIONAL
4.) PILOT TONE
5.) TEST
6.) RESET

B. <u>Secure and Non-Secure DCRD Signal Format Approval</u>

Range Safety shall approve the specific signal format.

C. <u>Secure and Non-Secure DCRD Telemetry Outputs</u>

The DCRD shall provide telemetry outputs that verify commands and the state-of-health of the system including internal monitoring/reporting for faults such as memory error and destruct-before-arm.

D. <u>Secure and Non-Secure DCRD Signal Outputs</u>

The DCRD shall provide an output, when receiving a valid arm and destruct command that shall product an electrical signal sufficient to initiate a destruct initiator.

E. <u>Secure and Non-Secure DCRD Environmental</u>

The DCRD shall be designed to operate in all environments specified in Phase 1 Part A Type 2 Goals: Environmental

F. <u>Secure and Non-Secure DCRD Components</u>

The Phase 1 Part A DCRD shall use the components projected to meet Qualification Unit Development and Proof of Concept Testing (Part C) requirements.

G. Secure and Non-Secure DCRD Command Signal Structure

1.) The command signal structure shall provide equivalent or greater security against inadvertent command as that currently existing with the high alphabet system described in EWR 127-1.
2.) The signal format shall minimize the probability of a command destruct signal from being jammed by an intentional or unintentional source.
3.) See Appendix B for additional notes on high alphabet.

3.4 Antenna (TBD)

3.5 Ground System Command Subsystem

A. The Phase 1 Part A designed ground command subsystem must be capable of end-to-end processing of commands from receipt at to be developed ground test terminal to transmission to WSC and insertion at the TDRSS forward link.

B. The equipment and software necessary to functionally test the DCRD through the TDRSS network shall be developed.

C. The equipment and software shall be designed to meet a reliability requirement in Phase 1 Part C of 0.999.

D. The Phase 1 Part A system may be an engineering test unit, but it must provide all command functions defined in this section.

3.6 Consideration for Future Requirements

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The following parameters are listed to permit early anticipation of requirements for Phase Two:

A. Noise figure will be specified as a state-of-health parameter. Intent is to provide a measure-of-merit to verify consistent performance as the unit progresses through factory acceptance and bench testing.

B. Immunity to In-Band and Out-of-Band interfering signals will be specified as a state-of-health parameter.

C. Phase linearity will be specified as a state-of-health parameter. Linearity as a function of frequency across in-band frequencies can be verified as a pre-assembly RF filter check.

D. Bandpass Characteristics (3 dB, 60 dB, and amplitude ripple) will be specified as a state-of-health parameter.

E. Peak Input Voltage (typical value – 45 volts) will be specified and meet launch vehicle worse-case power source capabilities.

F. Rapid Relock Capability (reacquisition time after loss of tracking on a channel) requires specific Range Safety approval; 500 ms should be used as a design goal.

4.0 PHASE 1 PART B: FEASIBILITY ANALYSIS AND DETAILED SPECIFICATION DEVELOPMENT

4.1 Part B: Feasibility Analysis And Detailed Specification Development Overview (TBD)

4.2 Analysis: Results of Part A DCRD Development (TBD)

4.3 Analysis: Space-Based System Feasibility (TBD)

4.4 Specification Development: DCRD (Refined), Ground Transmitter, and Commanding System (TBD)

5.0 PHASE 1 PART C: QUALIFICATION UNIT/GROUND SYSTEM DEVELOPMENT AND TESTING

5.1 Phase 1 Part C: Qualification Unit/Ground System Development And Testing Overview

5.1.1 Phase 1 Part C Objectives

Phase 1 Part C shall consist of the following:

A. Translate the designs from Phase 1 Part B into a flight worthy component and demonstrate performance in the operational environment.

B. Confirm ability to withstand representative flight environments via dynamic ground testing for conditions typically used for qualification testing of Range Safety components (shock, vibration, etc).

C. Expose RF system to acceptance and operational flight dynamic environment (e.g. shock, thermal and vibration).

D. Construct a working model of the ground test terminal proposed in Part A.

E. Demonstrate end-to-end message processing from the ground test terminal to the WSC.

F. During this test, demonstrate link closure with TDRSS and ability to receive, process, decode, and properly act upon the full range of operational commands defined in 7.5.

G. Integrate the flight hardware onto a launch vehicle. During the test flight, commands shall be sent from a test terminal to WSC through TDRSS to the DCDR located on the flight vehicle. The DCDR destruct command shall be output to a TM channel and be monitored during flight. To perform this test the following issues shall be addressed:

1.) A power source needs to be provided for the flight demonstration test. This power source can be supplied by the existing launch vehicle system or separate power source can be provided.

2.) Integration of the output signals from the DCDR shall be integrated with vehicle telemetry and provided for evaluation by ground receiving stations. Depending on launch vehicle system, a separate TM system may need to be supplied.

3.) The antenna system must be integrated onto the vehicle that allows proper link capability to the TDRSS system.

5.1.2 Proof of Design Testing

Proof of design testing will verify:

- Capability of the DCRD to maintain lock in simulated high dynamic environments. This testing may include use of a rotating mock-up to simulate typical vehicle roll rate and lever arm. Simulation testing should employ the NASA forward link signal structure in accordance with the ICD operationally and use representative input power.

- Characterize performance parameters. This characterization includes performance parameters listed in this document as well as additional parameters identified by the vendor.

- All testing and results shall be documented in test results reports.

5.2 Unit Flight Testing: Closed Loop/Open Loop

5.2.1 FTS Secure Digital Receiver and Decoder Prelaunch Tests{ XE "FTS Secure Receiver and Decoder Prelaunch Tests" }

A. Initial DCRD RF Open-Loop Tests**{** XE "Initial CRD RF Open-Loop Tests" **}**

1.) After installation of the command and automatic FTS up to, but not including, electrical and/or optical connection of flight destruct initiators and loading of the DCRDs with secure flight codes, an RF Open-Loop test of the FTS command system shall be performed.

2.) The Open-Loop test is conducted to prove the integrity of the ground and airborne command transmitter system (including the Range Command transmitter systems, vehicle antenna systems, and DCRDs) up to the point at which the flight destruct initiators will be electrically and/or optically connected.

3.) These tests shall be conducted as late in the Range User launch vehicle processing as practical. The configuration and performance requirements for this test are as follows:

(a) Destruct initiator simulators shall be installed in place of the flight initiators to verify that sufficient energy is delivered by the FTS command system to initiate destruct.

(b) The FTS command system can be powered by either flight or ground power.

(c) Each DCRD on the vehicle shall be loaded with the appropriate maintenance codes.

(d) All DCRD commands required by the program shall be transmitted to the vehicle open-loop by Range Command transmitters using maintenance codes.

(e) All DCRDs and primary and backup components in the Range Command transmitter system shall be verified as operational.

B. Command Closed-Loop and Automatic End-to-End Tests**{** XE "Command Closed-Loop and Automatic End-to-End Tests" **}**

1.) Following the loading of the DCRDs with the required secure flight codes, but prior to electrical and/or optical connection of the flight destruct initiators, a Command Closed-Loop and Automatic End-to-End test of the entire command and automatic FTS shall be performed.

2.) The Command Closed-Loop and Automatic End-to-End test is conducted to prove the integrity of the airborne FTS system including DCRDs, flight batteries, engine shutdown valves, and the automatic destruct system up to the point at which the flight destruct initiators will be electrically and/ or optically connected.

3.) The Command Closed-Loop and Automatic End-to-End Test shall be conducted as late in the Range User countdown as possible but not earlier than 48 h prior to launch if the FTS access compartment can be closed out. **NOTE:** If the FTS access compartment cannot be closed out 48 h prior to launch, the Command Closed-Loop Automatic End-to-End test shall be performed later in the countdown at a time when the FTS component access compartment can be closed out.

4.) The configuration and performance requirements for the Command Closed-Loop and Automatic End-to-End test are as follows:

(a) Destruct initiator simulators shall be installed in place of the flight initiators to verify that sufficient energy is delivered by both command and automatic circuits to initiate the initiators.

(b) FTS command and automatic systems shall be powered by flight batteries.

(c) All secure DCRD commands required by the program shall be transmitted to the airborne DCRDs closed-loop by Range User provided ground signal generators located at the launch pads.

(d) All primary and redundant components and/or circuits in the vehicle command and automatic FTS system shall be verified as operational.

C. Command DCRD Closed-Loop Test
{ XE "Command CRD Closed-Loop Test." }

1.) After removal of the destruct initiator simulators and electrical and/or optical connections of all flight destruct initiators, a Command DCRD Closed-Loop test shall be performed.

2.) The Command DCRD Closed-Loop test is conducted to provide final pre-launch assurance that the airborne command destruct system (DCRDs and flight batteries) is functioning properly.

3.) The Command DCRD Closed-Loop test shall be performed as late in the Range User countdown as possible but not earlier than 60 min prior to launch or just prior to launch support tower rollback.

4.) The configuration and performance requirements for this test are as follows:

(a) All secure DCRD commands required by the program except DESTRUCT shall be transmitted to the airborne DCRD closed-loop by Range User provided ground signal generators located at the launch pads.

(b) Each DCRD shall be tested and verified as operational.

D. Final DCRD RF Open-Loop Tes{ XE "Final CRD RF Open-Loop Tes" }t

1.) Prior to launch, a final RF open-loop test of the DCRD shall be performed.

2.) The Final DCRD RF Open-Loop test is conducted to provide final prelaunch assurance that the Range Command transmitter systems, FTS antenna systems, and DCRDs are functioning properly.

3.) The Final DCRD RF Open-Loop test shall be performed after the command closed-loop test but prior to launch.

4. The configuration and performance requirements for this test are as follows:

(a) All FTS arming devices are to remain in the SAFE position.

(b) The DCRDs are powered by flight batteries.

(c) The only command that will be transmitted open-loop to the vehicle DCRDs by the Range Command transmitters will be the TEST command. **NOTE:** If the DCRD successfully receives and decodes this command, it will initiate a self-test.

(d) All DCRDs and primary and backup Range Command transmitter systems shall be tested and verified as operational.

(e) Following a successful open-loop test, DCRDs (powered from flight batteries) and primary Range Command transmitter shall remain on through launch. **NOTE:** The WR requires that the Range Command transmitter transmit PILOT TONE continuously through lift-off.

5.2.2 WR Secure DCRD Post-Flight Open-Loop Verification Test{ XE "WR Secure CRD Post-Flight Open-Loop Verification Test" }

A. A Post-Flight Open-Loop Verification test shall be performed at the WR following a successful launch and flight. **NOTE:** Secure FTS codes are declassified following a successful flight.

B. The Post-Flight Open-Loop Verification test is conducted to demonstrate that the Range Command transmitter system would have been able to generate and transmit flight termination commands if the vehicle had required destruct action. **NOTE:** This verification test provides assurances that the secure code loading procedures and the closed and open-loop testing performed pre-flight were written and executed properly. The exact time for this post-flight test shall be established by Range Safety and Range User agreements.

C. The configuration and performance requirements for this test are as follows:

1.) Prior to launch, the post-flight verification DCRD under RFML control shall be loaded with the same secure FTS codes that are loaded into the vehicle DCRDs.

2.) As soon as possible after a successful flight, the Range shall issue and transmit open-loop all FTS command functions as applicable.

D. The post-flight verification DCRD, located in a mobile van under the control of RFML personnel, shall receive and decode all functions.

6.0 DOCUMENTING THE PROGRAM

6.1 Documenting the DCRD Program Overview

This section identifies specific methods/vehicles for documenting the DCRD program for audit trail purposes and future reference.

6.2 DCRD Detailed Component and System Descriptions

The detailed system description includes a complete and detailed narrative description of all of the major components of the DCRD. The following items are included:.

A. Narrative Description

A complete and detailed description of the DCRD operation including all possible scenarios and discussion of how DCRD components function at the system and piece part level. A complete and detailed description of each DCRD component and how it functions, including specifications and schematics, mechanical and piece part specifications, and operating parameters

B. Detailed Schematics and Drawings

Detailed schematics of the complete DCRD showing component values such as resistance, capacitance, and wattage; tolerance; shields; grounds; connectors and pin numbers; and telemetry pick-off points. The schematics shall include all proposed vehicle components and elements that interface with or share common use with the DCRD. All pin assignments shall be accounted for. Drawings showing the location of all DCRD system and subsystem components on the vehicle, including the following descriptions:

1.) Descriptions of element siting, mounting (attach points), and cable routing for physical isolation

2.) Descriptions of electrical connectors and connections and the electrical isolation of the DCRD

C. Illustrations

An illustrated parts breakdown of all mechanically operated DCRD components

6.3 Technical Interchange Meetings

Separate and independent RSS concept design reviews, preliminary design reviews, critical design reviews, and technical interchange meetings concerning the design of the proposed system shall be held with Range Safety participation. Some of these reviews may be performed by teleconference.

6.4 Reporting Component Failure to Meet System Test Requirements

Failure noted during testing shall be reported to Range Safety. Results of failure analysis and corrective action must be submitted to Range Safety for review and approval.

6.5 Modifications

Hardware and software configuration shall be maintained at the completion of Phase One Part A. Any changes made to the approved design must be approved by Range Safety prior to implementation of Phase 1 Part C.

6.6 Test Results Reports

Results from all test activities shall be documented in detail to define the actual test configurations, test purposes, test objectives (PASS/FAIL), all actual test results, and analysis of the data obtained during the test for evaluation by DCRD management.

ACRONYMS AND ABBREVIATIONS

(TBS)

Appendix B

Notes on High Alphabet Recommendation

GSFC requested more direction on the requirement to use the High Alphabet coding scheme. The following are answers from ER and WR to questions from GSFC.

a.) Will we be held to this scheme for the DCRD?

General Response: Range Safety recommends that the High Alphabet scheme be maintained in the DCRD design for the following reasons. There is currently a lot of discussion nationally over encrypting the Range Safety Command links to vehicles (KI-23). We feel that this will add unnecessary complexity to hardware on the ground and on the vehicle and not be as robust as the high alphabet implementation. The high alphabet scheme has NSA approval and we feel that if we maintain the scheme, we can assume approval from the NSA without their review. Secondly, if the scheme is maintained, the interface for NSA code loads at the command sites and on the vehicle (launch site) will not require modification. ER and WR recommend we maintain the High Alphabet Scheme

b.) Who is the authority on the required encryption needed for range safety activities?

No one currently. There is some discussion of this being taken on by an Ad-Hoc committee under the Range Safety Group of the Range Commanders Council. At any rate, this is not an issue for the test program. When DCRD becomes operational, and if the High Alphabet scheme is maintained, there should be not be any issue with the NSA.

c.) What is the minimum digital encryption needed to meet the current encryption scheme?

Recommend 11 characters and a minimum of 6 (5 “commands” plus 1 Pilot Tone command) possible “commands”. Each character consists currently as the sum of 2 of the possible 6 commands. These 11 characters correspond to one command. Two commands (Arm and Destruct) are required to initiate firing of the ordnance (vehicle destruct). Overall, a minimum of 22 characters is required to initiate vehicle destruct.

d.) How does ER plan to operate the link for encryption...will each command be encrypted or will the entire data stream be encrypted (the latter preferred)?

For the test program this is not an issue. For the operational system we recommend that encryption not be used. We may have a semantics problem with the use of the word encryption. The secure codes (11 character sequences of pairs of 7 possible “tones”) are treated as classified and are secured within a safe. One could consider these codes as encrypted. We do not currently radiate "secure" codes open loop unless the vehicle is in flight and arm and/or destruct action is required.. These are checked in a closed loop configuration from the Flight termination switches to the command site and a process exist to perform a closed loop check of the vehicle CRD with GSE owned and operated by the range users. Range Safety monitors these verification tests. The checks, which are performed open loop between the command site and the vehicle, are done with test or maintenance codes/commands.

e.) If held to this encryption scheme, we gather from the EWR 127.1 that there are 11 characters per message. How many bits are in a character? This has a direct impact to the data rate.

We again recommend that the link not be encrypted. The secure codes may be considered encrypted. To maintain the High alphabet scheme, a minimum of three bits (8 possible combinations) will be required to encode the 5 possible commands and 1 pilot command. Extending this by a bit to increase possible "command" combinations could be considered. Keep in mind that any added "commands" are not available in the current NSA code loading system.
Comment: The other potential scheme is a 49-50 bit binary sequence that produces roughly the same number of combinations as the high alphabet scheme. This may be more efficient but will require a change in NSA code load equipment and may require the NSA to review the new scheme. While Range Safety does not recommend the encrypted command path we do understand that uses of the secure path for other than the Range Safety application may require encryption. An alternate suggestion here may be to use a sequence of high alphabet codes specifically to gain access through the DCRD system to the vehicle systems. These one time codes (as many as necessary) would specify a path through the DCRD to the vehicle systems. They would be valid following the use of the system for Range Safety purposes. The high alphabet system would be used to provide a "secure" gateway to the vehicle systems. Obviously, there are many other ways to accomplish this as well.